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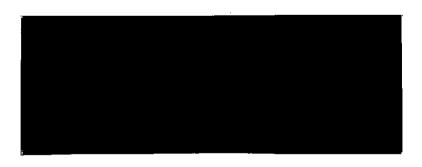
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(NASA+CR-134133) DEVELOPMENT OF
FLAME-RESISTANT STRUCTURES FOR USE IN THE
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DEVELOPMENT OF FLAME-RESISTANT STRUCTURES FOR USE IN THE APOLLO AND SKYLAB PROGRAMS

> Contract No. NAS 9-12418 FINAL REPORT September 1973

DEVELOPMENT OF FLAME-RESISTANT STRUCTURES FOR USE IN THE APOLLO AND SKYLAB PROGRAMS

Contract Number NAS 9-12418

Prepared by

Robert J. Coskren

for

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Structures and Mechanics Division
Houston, Texas

September 1973

FRL, An Albany International Company 1000 Providence Highway Dedham, Massachusetts

## INTRODUCTION

The purpose of this program has been to develop candidate flame-resistant textile structures for use in the Apollo and Skylab programs. Materials have been designed and fabricated to meet certain end-use criteria established by NASA with emphasis on meeting established flammability standards. The program had three general phases:

- 1. Fabrication of candidate sample structures for evaluation by the Structures and Mechanics Division and/or NASA contractors.
- 2. Physical testing of the structures developed.
- 3. Supply of required quantities of specific items for fabrication into prototype and/or flight items for the Apollo and Skylab programs.

During the course of the work discrete tasks were delineated from time to time by NASA and acted upon by FRL. A listing of the disposition of the various tasks assigned during the course of the program is given below. Also shown is a list of the various certified items produced under Contract Numbers NAS 9-7397 and NAS 9-12418.

Task	Description	Initiation Date	Completion Date	Monthly Report Reference
201	Fabricate 50 yards of PBI Raschel Net (S-164)	1/14/72	1/26/72	March 72
202	Fabricate 400 yards of Nat. Nomex Raschel Net (S-173)	1/14/72	1/26/72	March 72
203	Fabricate the following: 1. 35 yds PBI Fabric (S-159) 2. 25 yds PBI Fabric (S-165)	1/14/72	2/29/72	March 72
204	Fabricate 50 yards of PBI Woven Fabric (S-151)	1/14/72	2/25/72	March 72
205	Fabricate 50 yards of Nat. Nomex Webbing (S-174)	1/26/72	1/31/72	March 72
206	Investigate T-treatment of Various PBI structures	2/15/72	4/30/72	Mar-Jun 72
207	T-treat 15 yards of PBI Raschel Net (S-164FX)	2/29/72	2/29/72	March 72
208	T-treat 30 yards of PBI rib knit fabric (S-161FX)	3/10/72	3/10/72	April 72

Task No.		nitiation Date	Completion Date	Monthly Report Reference
209	T-treat the following: 1. 28 yds S-165 PBI fabric 2. 36 yds S-159 PBI fabric 3. 20 yds S-164 PBI raschel 4. 33 yds S-151 PBI fabric	3/15/72	3/17/72	April 72
210	T-treat the following: 1. 55 yds S-111 PBI webbing 2. 50 yds S-143 PBI webbing 3. 40 yds S-169 PBI webbing	3/29/72	4/10/72	April 72
211	Fabricate the following: 1. 50 yds S-143 PBI webbing 2. 20 yds S-170 PBI webbing	3/29/72	4/19/72	Apr-May 72
212	Fabricate 100 yards of S-169 PBI webbing	3/29/72	3/30/72	April 72
213	Fabricate and T-treat the following:  1. 390 yds PBI raschel (S-164FX  2. 575 yds PBI rib knit (S-177F)  3. 335 yds PBI fabric (S-165FX)  4. 200 yds PBI fabric (S-159FX)  5. 150 yds PBI webbing (S-169FX  6. 200 yds PBI webbing (S-143FX)	) X) )	8/29/72	May-Sept 72
214	Fabricate 48 PBI towels and washcloths	4/21/72	5/19/72	May 72
215	T-treat 44 yards of PBI webbing	4/24/72	4/21/72	May 72
216	Convert R.H. zippers to L.H. zippers	5/ 3/72	5/ 4/72	May 72
217	Fabricate stretch fabrics from T-treated PBI and Spandex yarn	5/18/72	5/22/72	June 72
218	T-treat PBI towels and wash- cloths made under Task 214	5/24/72	5/17/72	June 72
219	Fabricate stretch fabric from T-treated PBI and ADL elasto- meric yarn	5/30/72	6/ 1/72	June 73
220	Fabricate and T-treat 50 yards of PBI webbing (S-141FX)	6/ 6/72	6/ 8/72	Jun-Jul 72
221	T-treat 25 yards of PBI Braided Cord (S-121FX)	6/ 6/72	6/ 2/72	July 72

Task No.		nitiation Date	Completion Date	Monthly Report Reference
222	Fabricate and T-treat the following:  1. 50 yds PBI woven fabric (S-151FX)  2. 150 yds PBI webbing (S-141FX)  3. 150 yds PBI webbing (S-143FX)		8/31/72	Jul-Sept 72
223	Fabricate 7 yards of stretch fabric using T-treated PBI and ADL elastomeric fiber	8/11/72	7/11/72	Jul-Aug 72
	T-treat 25 yards of PBI braided cord (S-121FX)	8/ 8/72	6/26/72	July 72
225	T-treat the following: 1. 155 ft PBI webbing (S-101FX) 2. 73 ft PBI webbing (S-169FX)	8/-8/72	7/14/72	Aug 72
226	Fabricate PBI Wrapped ADL elastomeric yarns	8/ 9/72	7/31/72	Aug 72
227	Fabricate stretch knit fabrics from yarns made under Task 226	8/ 9/72	9/28/72	Aug-Oct 72
228	Fabricate 12 yards of flat jersey knit fabric (S-181)	8/ 9/72	9/ 8/72	Aug-Oct 72
229	Conduct PBI yarn processing trials at Southeastern Mass. University	8/14/72	9/12/72	Aug-Oct 72
230	Fabricate 100 yards of elastic tape from T-treated PBI yarn (transferred to Task 238)	8/25/72	1/12/73	Oct 72
231	T-treat 165 yards of PBI Braided Cord (S-121FX)	8/25/72	8/22/73	Oct 72
232	Microscopic analysis of fibrous components from SMEAT chamber	9/13/72	10/25/72	Oct 25, 72 special report
233	Fabricate and T-treat 800 yards of PBI rib knit fabric (S-177FX)	10/19/72	11/ 3/72	Oct-Nov 72
234	Fabricate 1000 yards of PBI braided cord (S-121)	11/ 3/72	11/20/72	Dec 72
235	Fabricate 25 yards of flat knit jersey fabric (S-181)	11/20/72	1/ 8/73	Dec 72 - Feb 73

Task	Description	Initiation Date	Completion Date	Monthly Report Reference
236	Fabricate 50 yards of 1-1/4" wide PBI webbing (S-168)	11/20/ <b>7</b> 2	11/21/72	Dec 72
237	T-treat 75 yards of one inch wide PBI webbing (S-141FX)	11/30/72	11/28/72	Dec 72
238	Fabricate 107 yards of elastic tape from T-treated PBI yarn and ADL elastomeric fiber (S-185FX and S-186FX)	12/ 8/72	1/12/73	Jan-Feb 73
239	T-treat the following PBI webbings: 1. 14 yds FRL Style No. S-157 2. 25 yds FRL Style No. S-143	1/31/73	1/19/73	Feb 73
240	Fabricate and T-treat 100 yards of 2 inch wide PBI webbing (S-157FX)	1/31/73	1/25/73	Feb 73
241	T-treat 110 yards of PBI braided cord (S-136FX)	3/15/73	3/ 8/73	Apr 73
242	Fabricate and T-treat the following PBI webbings: 1. 100 yds FRL Style No. S-141 2. 100 yds FRL Style No. S-169		4/ 3/73	Apr 73
243	Fabricate and T-treat 100 yard of broad woven PBI Fabric (S-151FX)	is 5/ 9/73	6/15/73	Jun 73
244	Fabricate 4000 ft of 1/4" diameter PBI braided cord (S-136)	9/10/ <b>7</b> 3	5/21/73	Jun 73
245	Fabricate the following: 1. 1000 ft T-treated PBI braid (S-136FX) 2. 700 ft 1" wide PBI webbing (S-188) 3. 5 lbs of PBI sewing thread (S-152) 4. 600 ft 3/32" diameter PBI braid (S-121)	9/10/73	6/25/73	Jul 73
246	Fabricate 900 feet of 1/4" diameter PBI braided cord (S-136)	9/10/73	6/12/73	Jun 73
247	Fabricate 25 yards of elastic braid from PBI yarn and ADL elastomeric fiber	9/10/73	7/ 3/73	Jul 73
248	T-treat 15 yards of 1/4" diameter PBI braided cord (S-136FX)	9/10/73	7/11/73	Aug 73

## LIST OF CERTIFIED ITEMS PREPARED UNDER CONTRACTS NAS9-7397 and NAS-9-12418

FRL Style No.	FRL Lot No.	Description
	TRE LOC NO.	30502290300
S-101	397-19,26,61, 63,182,190, 211,402,425	l" wide helmet tie down webbing
S-101FX	418-75	T-treated 1" wide PBI webbing
S-102	397-29,33	1/4" diameter PBI braided cord
S-103	397-34,98,369	1-3/4" wide PBI webbing
S-104	397-39	PBI raschel knit for debris net
s-105	397-46,89	1-3/4" PBI webbing
S-106	397-56	1/4" daimeter PBI braided cord (CNR treated)
S-108	397-62	1/8" daimeter PBI braided cord
S-109	397-38,191, 426,438	1/4" diameter PBI braided cord
s-110	397-58	Beta tricot liner fabric
s-111	397-81,193	l" wide PBI webbing
S-111FX	418-41	1" wide PBI webbing (T-treated)
S-112	397-86	3/8" wide Beta tape (Teflon coated)
s-113	397-87	1/8" Teflon coated Beta braided cord
S-114	397-90	Teflon coated Beta raschel knit
s-115	397-97,101, 101A,121	Teflon coated Beta broad fabric
S-116	397-103	Teflon coated Beta yarn raschel knit debris net
S-117	397-104,106	13/16" wide PBI webbing +
S-118	397-105	1-3/4" wide PBI webbing

FRL Style No.	FRL Lot No.	Description
S-119	397-107	PBI sewing thread
S-120	397-128	1/16" diameter Teflon coated Beta yarn braid
S-121	397-137,149, 151,459, 418-132,170	3/32" diameter PBI braided cord
S-121FX	418-60,71,87	T-treated 3/32" diameter PBI braided cord
S-122	397-140A	1/16" diameter PBI braided cord
S-123	397-141	3/32" diameter PBI braided cord
S-124	397-150,184, 195,314,433	1-1/4" wide PBI webbing
S-125	397-152	Teflon coated Beta yarn tricot fabric
S-126	397-157	Teflon coated Beta yarn braid, 3/64" diameter
s-127	397-163,175	Teflon coated Beta yarn, 1/32" diameter braid
s-130	397-197	Natural Teflon yarn 3/200-300-20S/10Z
s-131	397-199	Natural Teflon yarn 5/400-60-0/3Z
S-132	397-200	Karma broad fabric
s-133	397-201	Karma broad fabric
s-134	397-208,301 463	Teflon tape, natural brass teeth, slide fasteners
S-135	397-209	Teflon coated Beta/Teflon ortho fabric
S-136	397-214 418-161,165	1/4" daimeter PBI braided cord
s-136FX	418-155,164, 172	T-treated 1/4" diameter PBI braided cord
s-137	397-225	Filament PBI tricot fabric
S-138	397-229	Beta raschel tricot fabric for thermal blanket
s-139	397 - 231	Teflon coated 450 1/3 Beta yarn
s-140	397-232	Viton A unsupported gloves
s-141	397-224,250, 384,436,450, 418-65,156	l" wide PBI webbing

FRL Style No.	FRL Lot No.	Description
S-141FX	418-61,67, 137,157,160	l" wide PBI webbing (T-treated)
S-142	397-248	6 ounce spun PBI fabric (antistat finish)
S-143	397-249,287, 373,424,451 418-39,66	1-1/2" wide PBI tape
S-143FX	418-24,43,45, 62,68,147	1-1/2" wide PBI tape (T-treated)
S-144	397-251,321, 460	1/2" wide PBI tape
S-145	397-252	Teflon coated Beta yarn raschel fabric
S-146	397-253	Teflon coated Beta yarn raschel fabric
S-147	397-285	3/4" wide PBI tape
S-148	397-288,363, 371	1-1/2" wide Nomex tape
S-149	397-311	PBI double knit glove fabric
S-150	397-309	9/16" wide PBI tape
S-151	397-336, 418-9,21,92	6 ounce spun PBI 2/1 twill fabric (antistat finish)
S-151FX	418-28,97	6 ounce PBI 2/1 twill fabric (antistat finish, T-treated)
S-152	397-339,401 418-166	3 ply PBI sewing thread
S-153	397-356	Natural Nomex simplex knit
S-154	397-372,447 67877-114-3	1-1/4" wide PBI webbing
S-154FX	418-38	1-1/4" wide PBI webbing (T-treated)
S-157	397-455 67877-114-2 418-148	2" wide PBI webbing
S-157FX	418-146,150	2" wide PBI webbing (T-treated)
S-158	397-409	3 ounce spun PBI broad fabric
S-159	397-410,444 418-11,20,85	7 ounce fancy twill spun PBI fabric

FRL Style No.	FRL Lot No.	Description
	418-29,91	7 ounce fancy twill spun PBI fabric (T-treated)
S-161	397-437	1 x 1 PBI rib knit
S-161FX	418-23	1 x 1 PBI rib (T-treated)
S-162	397-417	3/8" wide PBI tape
S-163	397-420,421	PBI covered spandex rib knit
S-164	397-423 418-3,50	Spun PBI raschel knit
S-164FX	418-12,13,27, 55,64	Spun PBI raschel knit (T-treated)
S-165	397-445 418-6,19	4 ounce plain weave PBI broad fabric
S-165FX	418-30,70	4 ounce plain weave PBI broad fabric (T-treated)
S-166	397-434,435, 454	3/4" wide PBI tape
S-168	397-449 418-136	1-1/4" wide PBI webbing
S-169	397-458 418-40,158	1-3/4" wide PBI webbing
S-169FX	418-42,63,74, 159	1-3/4" wide PBI webbing (T-treated)
s-170	397-457 418-44	1-3/4" wide PBI restraint harness webbing
s-171	397-462	Teflon tape, aluminum teeth, slide fastener
s-172	397-461	T-treated PBI broad fabric
s-173	418-4	Spun Nomex raschel net
S-174	418-5	1-3/4" wide Nomex restraint webbing
s-175	418-7	T-treated PBI spun fabric
S-176	418-22	PBI cord (8 ply, 3 cable)
s-177	418-49,90, 122	PBI rib knit
s-177FX	418-54,93, 126	PBI rib knit

FRL Style No.	FRL Lot No.	Description
S-178		PBI terry towelling
S-178FX	418-52	T-treated PBI terry towels
S-179FX	418-53	T-treated PBI terry washcloths
S-180	418-56	T-treated PBI yarn wrapped over spandex raschel fabric
S-181	418-69,72,73, 83-1,84,86,89, 98,100,142, 143,144	T-treated PBI yarn wrapped over ADL rubber flat knit fabric
S-182	418-81	Cabled PBI beading cord
S-183	418-82	16 carrier braid from 30/1 cc PBI yarn
S-184	418-83	12 carrier braid from 30/1 cc PBI yarn
S-185FX	418-140	3/4" wide elastic webbing (ADL rubber)
S-186FX	418-141,145	1-1/2" wide elastic webbing (ADL rubber)
S-187FX	418-168	Plain weave T-treated spun PBI fabric (7.6 ounce) ASTP suit
S-188	418-169	l" wide PBI webbing similar to MIL-W-4088, type II, Nomex
S-189	418-171	PBI/ADL elastomeric-fiber braided cord (16 ends of rubber)